ADVANCED LEVEL PHYSICAL CHEMISTRY PROBLEMS

CHAPTER 8: CHEMICAL EQUILIBRIA

1. (a). During the manufacture of sulphuric acid by contact process, sulphur dioxide is oxidised to sulphur(VI) oxide according to the following equation.

$$2SO_2(g) + O_2(g) \leftrightharpoons 2SO_3(g)\,;\, \Delta H = -188kJmol^{-1}$$

State the effect on the yield of sulphur(VI) oxide if

(i). Temperature was increased

(ii). Pressure was decreased

(iii). Concentration of sulphur dioxide was increased

(b). Write equation to show how sulphuric acid can be obtained from sulphur(VI) oxide

2. Nitrogen monoxide combines with oxygen according to the following equation

$$2NO(g) + O_2(g) \leftrightharpoons 2NO_2(g)$$

(a). Write an expression for the equilibrium constant K_c

(b). 3.0 moles of nitrogen monoxide and 1.5 moles of oxygen were put in a 1 litre vessel. When equilibrium was attained, the vessel was found to contain 0.5 mole of oxygen. Calculate the equilibrium constant Kc at this temperature.

(c). When temperature was raised to 500 °C, the mixture in (b) was found to contain 25% of the initial nitrogen monoxide. Calculate the equilibrium constant K_c at this temperature.

(d). From your answers in (b) and (c), deduce whether the process is endothermic or exothermic.

3. Consider the reaction between sulphur dioxide and oxygen to produce sulphur trioxide at 700°C.

$$2SO_2(g) + O_2(g) \leftrightharpoons 2SO_3(g) \quad \Delta H = -ve$$

(a). Write the expression for the equilibrium constant, K_c, an state its units

(b). What happens to the sulphur trioxide in the equilibrium mixture if,

(i). Temperature was raised from 700 to 800°C.

(ii). More oxygen is added

(iii). More nitrogen is added

(iv). Volume of the reaction vessel is increased.

(c). The equilibrium mixture above at 700°C contains 0.4 mol of sulphur dioxide and 0.03 mol of oxygen and 1.00 mol of sulphur trioxide in 20 dm^3 container. Calculate the value of equilibrium constant K_c.

4. The reaction between nitrogen and hydrogen takes place as follows.

$$N_2(g) + 3H_2(g) \leftrightharpoons 2NH_3(g) \quad \Delta H = -ve$$

(a). Write the expression for the equilibrium constant, K_c, for the forward reaction

(b). At 500°c, the equilibrium concentration of hydrogen is 0.25 moldm^{-3} and that of nitrogen is 0.27 moldm^{-3}. Calculate the equilibrium concentration of ammonia at the same temperature given that the equilibrium constant, K_c is 6.0×10^{-2} mol^{-2}dm^6

(c). What would happen to the ammonia at equilibrium if

(i). Helium was added

(ii). Temperature was increased

5. (a). The degree of dissociation of 3.4 mole of hydrogen iodide at 460°C was found to be 20%. Calculate the

(i). Number of moles of hydrogen iodide, hydrogen and iodine formed at equilibrium

(ii). Equilibrium constant, K_c, for the dissociation reaction.

(b). A mixture containing 28 moles of hydrogen and 22 moles of iodine was heated in a sealed tube at 460 °C until equilibrium was attained when 36 moles of hydrogen iodide was obtained. Calculate the degree of dissociation of hydrogen iodide at 460°C.

6. (a). In the Haber process, ammonia is synthesised from nitrogen and hydrogen.

(i). Write the equation for the reaction leading to the formation of ammonia

(ii). Write an expression for the equilibrium constant, K_c.

(b). When nitrogen was reacted with hydrogen at 690K, the total pressure of the system at equilibrium was 32 atmospheres and the partial pressure of hydrogen and nitrogen were 8 and 3 atmospheres respectively. Calculate the

(i). Partial pressure of ammonia in equilibrium mixture

(ii). Equilibrium constant for the reaction

7. Phosphorus(V) chloride decomposes at high temperature according to the following equation

$$PCl_5(g) \leftrightharpoons PCl_3(g) + Cl_2(g)$$

When 40.2 g of phosphorus(V) chloride was placed in 4.5 litre vessel and heated at a certain pressure, 4.2g of chlorine was formed at equilibrium.

(a). Calculate the

(i). Amount of phosphorus(V) chloride and phosphorus(III) chloride at equilibrium in moles per litre.

(ii). Equilibrium constant, K_c, for the reaction and state its units

(b). State how the value of equilibrium constant would be affected and in each case, give a reason for your answer if

(i). The pressure was increased.

(ii). Some chlorine was removed.

8. Hydrogen and iodine react to form hydrogen iodide according to the equation

$$H_2(g) + I_2(g) \leftrightharpoons 2HI(g)$$

(a). (i). Write an expression for the equilibrium constant, K_c, for the reaction

(ii). 1 mole of hydrogen and $\frac{1}{3}$ mole of iodine were heated together at 450°C until equilibrium was attained. Calculate the number of moles of hydrogen iodide present in the equilibrium mixture at 450°C. (K_c for the reaction between hydrogen and iodine is 50)

(b). Briefly describe how the concentration of iodine in the equilibrium mixture can be determined.

(c). Describe an experiment to determine the equilibrium constant, K_c, for the decomposition of phosphorus(V) chloride.

9. (a). Ethanol reacts with ethanoic acid to form ethylethanoate according to the equation

$$CH_3COOH(l) \; + \; CH_3CH_2OH(l) \; \leftrightharpoons \; CH_3COOCH_2CH_3(l) \; + \; H_2O(l)\,; \;\; \Delta H = -ve$$

(i). State the conditions for the reaction

(ii). Describe how the equilibrium constant, K_c, for the reaction can be determined by a titrimetric method.

(b). Explain what would happen to the equilibrium constant if

(i). A catalyst was added

(ii). Temperature was increased

(c). A mixture of 0.69g of ethanol and 0.9g of ethanoic acid were allowed to react at 90°C until equilibrium was reached. Calculate the mass of ethylethanoate formed. (equilibrium constant, K_c, for the reaction is 3.6)

10. (a). At a certain temperature, the equilibrium constant for the reaction between nitrogen and hydrogen, K_p, is $4.82 \times 10^{-2}\ atm^{-2}$ and the partial pressures of nitrogen and hydrogen are 30 and 120 atm respectively

(i). Write the expression for the equilibrium constant. K_p, for the reaction

(ii). Calculate the partial pressure of ammonia at equilibrium

(b). 1 mole of sulphur trioxide was introduced into a $1dm^3$ vessel. The vessel was heated to 1000K until equilibrium was attained. At equilibrium, 0.35 mol of sulphur trioxide was present.

(i). Write equation for the decomposition of sulphur trioxide

(ii). Write an expression for the equilibrium constant, Kc.

(iii). Calculate the value of K_c.

11. Nitrogen(II) oxide combines with oxygen at 80°C and 200 atm to form nitrogen(IV) oxide according to the equation.

$$2NO(g) \; + \; O_2(g) \; \leftrightharpoons \; 2NO_2(g)\,; \; \Delta H = -ve$$

(a). (i). Write an expression for the equilibrium constant, K_p, for the reaction.

(ii). Calculate the value of K_p if the mixture contained 67% nitrogen(IV) oxide at equilibrium

(b). State how the value of K_p will be affected if

(i). Temperature was increased

(ii). A catalyst was added

12. Ethanol decomposes according to the following equation

$$CH_3CH_2OH(g) \leftrightharpoons CH_4(g) + CO(g)\,;\, \Delta H = -ve$$

(a). Write an expression for the equilibrium constant, K_p, for the reaction

(b). Explain how the value of K_p would be affected if

(i). Temperature was increased

(ii). Pressure is increased

13. (a). Write an

(i). Equation for the reaction between hydrogen and nitrogen

(ii). Expression for the equilibrium constant of the reaction in (i)

(b). When hydrogen was reacted with nitrogen at 895K, the total pressure of the system was 30 atm at equilibrium and the total pressure of nitrogen and hydrogen were 2 and 6 respectively. Calculate the equilibrium constant for the reaction

14. (a). Manganese(IV) sulphide reacts with acids according to the equation

$$MnS(s) + 2H_3O^+(aq) \leftrightharpoons Mn^{2+}(aq) + 2H_2O(l) + H_2S(aq)$$

State giving a reason in each case, what would happen to the equilibrium if

(i). Hydrogen chloride is bubbled in the equilibrium mixture

(ii). pH of the mixture is increased

(iii). The mixture was diluted with water.

(b). Hydrogen reacts with iodine according to the following equation

$$H_2(g) + I_2(g) \leftrightharpoons 2HI(g)$$

A mixture of 0.8 mole of hydrogen and 0.6 mole of iodine was allowed to react in a sealed tube at 450°C. at equilibrium, 0.2 mole of iodine had reacted.

(i). Write an expression for the equilibrium constant, K_c, for the reaction

(ii). Calculate the value of Kc at 450°C.

15. (a). State three characteristics of a chemical equilibrium.

(b). Phosphorus pentachloride decomposes when heated at 190°C according to the following equation

$$PCl_5(g) \leftrightharpoons PCl_3(g) + Cl_2(g)$$

Describe an experiment that can be carried out to determine the equilibrium constant, K_c, for the reaction

(c). Sulphur dioxide dichloride (sulphoryl dichloride) decomposes when heated according to the following equation.

$$SO_2Cl_2(g) \leftrightharpoons SO_2(g) + Cl_2(g)$$

When 67.5g of sulphur dioxide dichloride was heated in a 1 dm^3 vessel at 120°C and 3.6 atmospheres, it was found that at equilibrium, 45% of it had decomposed.

(i). Write the expression for the equilibrium constant, K_p.

(ii). Calculate the number of moles of each substance present at equilibrium.

(iii). Determine the value of the equilibrium constant, K_c.

16. Nitrogen reacts with hydrogen according to the equation

$$N_2(g) + 3H_2(g) \leftrightharpoons 2NH_3(g)$$

(a). Write an expression for the equilibrium constant, K_p, for the reaction and state its units

(b). Stoichiometric amounts of nitrogen and hydrogen were reacted at 40 atm and at equilibrium, 0.8 mole of ammonia was formed. Calculate the

(i). Amount of hydrogen at equilibrium

(ii). Value of the equilibrium constant, K_p

17. (a). In the industrial production of sulphuric acid by contact process, sulphur dioxide is oxidised to sulphur trioxide in the presence of a catalyst according to the equation.

$$SO_2(g) + \frac{1}{2}O_2(g) \leftrightharpoons 2SO_3(g);\ \Delta H = -96Kjmol^{-1}$$

(i). Name the catalyst used in the process

(ii). Explain why the reaction is carried out at 500°C

(iii). Sulphuric acid is used in the manufacture of superphosphate fertiliser. Write the equation for the reaction

(iv). Give one other large scale of sulphuric acid.

(b). Concentrated sulphuric acid contains 98% of the acid. Calculate the mass of concentrated sulphuric acid required to make 2.0M solution of sulphuric acid.

(c). Name one reagent that can be used to identify the anion in sulphuric acid. State what would be observed and write the equation for the reaction that takes place when the reagent you have named is used

18. Hydrogen reacts with nitrogen to produce ammonia according to the following equation

$$N_2(g) + 3H_2(g) \leftrightharpoons 2NH_3(g)$$

(a). Write the expression for the equilibrium constant, K_c.

(b). State giving reasons, what would happen to the value of equilibrium constant when

(i). Pressure is added to the equilibrium mixture

(ii). Argon is added to the reaction mixture at constant pressure

(iii). Argon is added to the reaction mixture at constant volume

19. Hydrogen iodide decomposes when heated according to the equation

$$2HI(g) \leftrightharpoons H_2(g) + I_2(g)$$

(a). Write an expression for the equilibrium constant, Kc, for the reaction

(b). 1.54g of hydrogen iodide was heated in a 600cm^3 bulb at 530°C. When equilibrium was established, the bulb was broken under potassium iodide solution. The iodine formed from the decomposition required 67.0cm^3 of 0.1M sodium thiosulphate solution for complete reaction. Calculate the

(i). Number of moles of hydrogen iodide in 1.54g
(ii). Number of moles of iodine formed
(iii). Value of equilibrium constant K_c.

(c). State what would be the effect on the value of Kc if
(i). Temperature was increased from 530 to 800°C.
(ii). The volume of the bulb was decreased to 120cm^3

20. (a). Discuss the effect of the following on the position of equilibrium of a reversible reaction, the rate of attainment of equilibrium and the value of equilibrium constant.
(i). Temperature
(ii). Pressure
(iii). Catalyst

(b). Write an expression for the equilibrium constant K_c or K_p as appropriate for the following reactions at equilibrium and indicate the units in each case.

$$2A + B \leftrightharpoons C + 3D$$

(i). A, B, C and D are all gases
(ii). A, B, C, and D are all liquids
(iii). A, B, C are solids and D is a gas

21. Phosphorus(V) chloride when heated decomposes according to the equation

$$PCl_5(g) \leftrightharpoons PCl_3(g) + Cl_2(g)$$

(a). A sample of pure phosphorus(V) chloride was heated in a 1 litre vessel to 250°C. When equilibrium was attained, the vessel was found to contain 40.7% chlorine. Calculate the
(i). Molar concentration of phosphorus(V) chloride at equilibrium
(ii). Equilibrium constant, K_c, for the reaction at 250°C.

(b). Explain what would happen to the concentration of chlorine if the pressure in the vessel was decreased at constant temperature.

22. Dinitrogen tetraoxide dissociates according to the equation

$$N_2O_4(g) \leftrightharpoons 2NO_2(g)\ ;\ \Delta H = +54kJmol^{-1}$$

(a). State and explain the effect of each of the following on the position and rate of attainment of equilibrium for the above reaction
(i). Increase in pressure
(ii). Increase in temperature
(iii). Increase in the volume of the vessel

(b). One litre of a gases mixture above at equilibrium was found to contain 57% of the original 2.8g of dinitrogen tetraoxide. Calculate the equilibrium constant K_c for the reaction.

23. (a). Distinguish between position of equilibrium and rate of attainment of equilibrium

(b). Sulphur dioxide dichloride, SO_2Cl_2, decomposes according to the equation

$$SO_2Cl_2(g) \leftrightharpoons SO_2(g) + Cl_2(g)$$

(i). Write the expression for the equilibrium constant, K_p.

(ii). Explain the effect on the equilibrium above when a catalyst is added.

(iii). At pressure of 1 atm and temperature of 100°C, a sample of sulphur dioxide dichloride was found to contain 34% of chlorine. Calculate the value of K_p.

(c). Phosphorus(V) chloride decomposes according to the equation.

$$PCl_5(g) \leftrightharpoons PCl_3(g) + Cl_2(g)$$

Deduce that the total pressure, $P_T = 3K_p$ when 50% of phosphorus(V) chloride has dissociated.

24. (a). Explain what is meant by the term **equilibrium constant**

(b). Discuss the effect of each of the following on the position of equilibrium, the rate of attainment and value of equilibrium constant

(i). Concentration

(ii). Temperature

(c). Carbon monoxide and steam react according to the equation,

$$CO(g) + H_2O(g) \leftrightharpoons CO_2(g) + H_2(g); \quad \Delta H = -40kJmol^{-1}$$

Equal moles of carbon monoxide and steam were made to react in a 1 litre vessel. When equilibrium was attained, the vessel was found to contain 16.7% carbon dioxide. Calculate the

(i). Molar concentration of carbon monoxide at equilibrium

(ii). Equilibrium constant, K_c, for the reaction

(d). If the percentage yield of ammonia from nitrogen and hydrogen at 700K and 200 atm is 15%. Calculate the equilibrium constant, K_p.

25. (a). Write an expression for the equilibrium constant, K_p or K_c as appropriate for the following at equilibrium and indicate units in each case.

$$P + Q \leftrightharpoons 2R + S$$

(i). P, Q, R and S are all gases

(ii). P, Q, R and S are all liquids

(b). Ammonium hydrogen sulphide dissociates according to the equation

$$NH_4HS(s) \leftrightharpoons NH_3(g) + H_2S(g)$$

At 298K, in a closed vessel, equilibrium was established when the partial pressure of the system is 0.88 atm.

(i). Write the expression for the equilibrium constant, K_p.

(ii). Calculate the value of K_p and give its units

(iii). Calculate the partial pressure of ammonia in the mixture if 0.1 atm of ammonia gas was added to the system.

26. (a). When 60g of ethanoic acid and 46g of ethanol were made to react to equilibrium at 100°C, the percentage of esterification was 54%
    (i). Write equation for the esterification reaction
    (ii). Calculate the value of K_c
    (iii). Write the mechanism for the reaction between ethanoic acid and ethanol
    (b). The degree of dissociation of 2.0 moles of phosphorus(V) chloride in a 1dm^3 vessel was founds to be 22%. Calculate the equilibrium constant, K_c, for the reaction.
    (c). The degree of dissociation of 0.5 moles of hydrogen iodide was found to be 25% at a certain temperature in a 1.5dm^3 vessel. Calculate the equilibrium constant, K_p.

27. (a). Carbon monoxide reacts with steam according to the following equation

$$CO(g) + H_2O(g) \leftrightharpoons CO_2(g) + H_2(g); \quad \Delta H = -40kJmol^{-1}$$

    (i). Write the expression for the equilibrium constant, K_c.
    (ii). Equal moles of carbon monoxide and steam were made to react in a 1 litre vessel. When equilibrium was established at 750°C, the vessel was found to contain 26.7% carbon dioxide. Calculate the equilibrium constant, K_c, for the reaction.
    (b). State, giving reasons, how the concentration of carbon dioxide would be affected if at equilibrium
    (i). Temperature was increased
    (ii). Pressure was increased
    (iii). Helium was added at constant volume.

28. Find the equilibrium constant, K_c, for the following
    (a). 2.0 moles of phosphorus(V) chloride that is 22% dissociated in a 1 litre vessel
    (b). 3.6 moles of phosphorus(V) chloride that is 38% dissociated in a 2 litre vessel
    (c). 1.8 moles of phosphorus(V) chloride whose degree of dissociation is 15% in a 1 litre vessel
    (d). 2.4 moles of phosphorus(V) chloride whose degree of dissociation is 35%,

29. (a). At a given temperature, 3.2 moles of phosphorus pentachloride dissociated so that at equilibrium, it was found to contain 20% chlorine. Calculate the value of K_c.
    (b). When 2.4 moles of phosphorus pentachloride were heated in a 1.5 dm^3 vessel and at equilibrium, it was found to contain 23.53% phosphorus trichloride
    (i). Write equation for the decomposition of phosphorus pentachloride
    (ii). Write the expression for the equilibrium constant K_p and K_c for the reaction
    (iii). Determine the value of equilibrium constant, K_c.

30. Find the equilibrium constant, K_c, for the following
    (a). 3.2 moles of phosphorus pentachloride were heated in a 2 litre vessel and at equilibrium, it was found to contain 53.85% phosphorus pentachloride

(b). 2.0 mole of phosphorus pentachloride were heated in a 1 litre vessel and at equilibrium, it was found to contain 1.48 mole of phosphorus pentachloride.

31. (a). When 2.6 mole of phosphorus(V) chloride was heated in a 1.5dm^3 vessel, equilibrium was established when 1.04 mole of phosphorus(III) chloride was formed. Calculate the value of equilibrium constant, K_c.
    (b). 3.0 mole of phosphorus pentachloride was heated in a 1 litre vessel and when equilibrium was attained, it was found to contain 1.14 mole of chlorine gas. Determine the value of equilibrium constant K_c.

32. (a). 2.6 mole of phosphorus pentachloride was heated in a 500cm^3 closed vessel. At equilibrium, it was found to contain 1.04 mole of phosphorus trichloride. Determine the value of equilibrium constant, K_c.
    (b). 2.0 mole of phosphorus(V) chloride was heated in a 800cm^3 closed vessel and at equilibrium, it was found to contain 1.48 moles of phosphorus trichloride. Calculate the value of equilibrium constant, K_c.
    (c). 3.0 mole of phosphorus pentachloride was heated in a 750cm^3 vessel until equilibrium was established. The vessel contained 1.14 moles of chlorine. Determine the value of equilibrium constant, K_c.

33. (a). 2.085g of phosphorus pentachloride was heated in a 1 dm^3 vessel until equilibrium was attained. The vessel was then broken under excess potassium iodide solution. The iodine liberated required 40cm^3 of 0.1M sodium thiosulphate solution. Determine the equilibrium constant, K_c, for the reaction.
    (b). 2.085g of phosphorus pentachloride was heated in a 400cm^3 vessel until was attained. The chlorine liberated was bubbled through a solution of potassium iodide. The iodine liberated required 20cm^3 of 0.2M sodium thiosulphate for complete reaction. Calculate the value of equilibrium constant, K_c for the reaction

$$PCl_5(g) \leftrightharpoons PCl_3(g) + Cl_2(g)$$

34. (a). Determine the composition of the equilibrium mixture if 83.4g of phosphorus pentachloride is heated in a 5 dm^3 vessel whose degree of dissociation is 20%, hence find the equilibrium constant K_c.
    (b). Ammonia decomposes according to the following equation

$$2NH_3(g) \leftrightharpoons N_2(g) + 3H_2(g)$$

Determine the equilibrium constant K_c for the reaction given 3.0 moles of ammonia were found to be 15% dissociated.

35. Find the equilibrium constant K_c for the following
    (a). 2.4 mole of ammonia heated in a 1 litre vessel and at equilibrium, it is found to contain 19.41% nitrogen.
    (b). 1.8 mole of ammonia was heated in a 1 litre vessel and at equilibrium it was found to contain 42.86% hydrogen.

(c). 2.5 mole of sulphur trioxide heated in a 2 litre vessel, and found to be 20% dissociated at equilibrium.
(d). 1.5 moles of sulphur trioxide heated in a 1 litre vessel whose degree of dissociation is 15% at a given temperature.

36. Nitrogen combines with hydrogen according to the equation

$$N_2(g) + 3H_2(g) \leftrightharpoons 2NH_3(g)$$

(a). Find the equilibrium constant, K_p, for the reaction given that the equilibrium mixture contains
(i). 20% ammonia at 110 atm of pressure
(ii). 50% ammonia at 700 atm of pressure
(iii). 45% ammonia at 600 atm of pressure
(b). Find the equilibrium constant, K_c, for the above reaction when
(i). 0.007 moles of nitrogen and 0.073 moles of hydrogen are heated and at equilibrium 0.01 moles of ammonia were formed
(ii). 0.2 moles and 0.47 moles of nitrogen and hydrogen respectively when heated to equilibrium in a 1 litre vessel and 0.18 moles of ammonia were formed
(iii). 0.03 moles of nitrogen and 0.05 moles of hydrogen are heated at equilibrium to from 0.015 moles of ammonia

37. (a). Find the equilibrium composition when 0.2 mole of phosphorus(V) chloride is heated in a 1 litre vessel until equilibrium is established ($K_c = 5.294 \times 10^{-3} moldm^{-3}$).
(b). Calculate the percentage of chlorine is the equilibrium mixture if 0.4 moles of phosphorus(V) chloride were heated in a 1 dm^3 vessel and the equilibrium constant is $0.02 moldm^{-3}$.
(c). Determine the mass of each of the substance at equilibrium when 0.52 moles of phosphorus(V) chloride is heated at equilibrium. ($K_c = 0.043 moldm^{-3}$)

38. (a). Hydrogen chloride decomposes according to the equation

$$2HI(g) \leftrightharpoons H_2(g) + I_2(g)$$

Given that the equilibrium constant for the reaction is 0.02. Calculate the equilibrium composition of the following if they are heated.
(i). 0.2 mole of hydrogen iodide.
(ii). 0.15 mole of hydrogen iodide.
(iii). 0.05 mole of hydrogen iodide.
(b). When 0.4 mole of hydrogen iodide was heated to equilibrium, it dissociated.
(i). Write equation for the dissociation of hydrogen iodide
(ii). Write the expression for the equilibrium constant, K_c.
(iii). Determine the degree of dissociation of hydrogen iodide, given that the equilibrium constant is 0.025

39. Hydrogen reacts with iodine according to the equation

$$H_2(g) \ + \ I_2(g) \ \leftrightharpoons \ 2HI(g)$$

(a). Find the equilibrium concentration of each of the following
  (i). 0.2 mole of iodine and 0.3 moles of hydrogen are reacted in a 1dm^3 vessel
  (ii). 0.25 mole of iodine and 0.4 mole of hydrogen are reacted in a 2 litre vessel
  (iii). 0.42 moles of iodine and 0.26 moles of hydrogen are reacted in a 1.5 dm^3 vessel. Give that the equilibrium constant, K_c, for the reaction is 50

(b). Equimolar quantities of iodine and hydrogen were heated in a 1 litre vessel until equilibrium was attained and it was found to contain
  (i). 25.2% hydrogen iodide
  (ii). 13.5% hydrogen iodide
  (iii). 20.5% hydrogen iodide
  Determine the equilibrium constant, K_c, in each case.

40. (a). 0.03 moles of nitrogen and 0.09 moles of hydrogen were heated in a 1 dm^3 vessel until equilibrium was attained at 299K. If at equilibrium, the vessel contained 0.056 moles of ammonia
  (i). Write the equation for the reaction
  (ii). Write the expression for the equilibrium constant, K_p.
  (iii). Determine the equilibrium constant, K_p.

(b). Nitrogen dioxide decomposes when heated according to the equation.

$$2NO_2(g) \ \leftrightharpoons \ 2NO(g) \ + \ O_2(g)$$

  (i). Write the equilibrium expression, K_c for the reaction
  (ii). Determine the value of K_c.

41. (a). Sulphur dioxide decomposes according to the equation when heated

$$2SO_3(g) \ \leftrightharpoons \ 2SO_2(g) \ + \ O_2(g) \ ; \ \ \Delta H = +ve$$

  (i). State the conditions for the reaction
  (ii). Write an expression for the equilibrium constant for the reaction, K_p

(b). When sulphur trioxide was heated in a closed vessel, at 270°C and 0.25 atmospheres, 46% of sulphur trioxide was decomposed at equilibrium. Calculate the value of K_p

(c). Calculate the heat of decomposition of sulphur trioxide (the heat of formation of sulphur dioxide and trioxide are -279 and -392 $kJmol^{-1}$)

(d). Explain how the position of the equilibrium, value of equilibrium constant and the rate of attainment of equilibrium would be affected if
  (i). The temperature of the reaction was increased
  (ii). The pressure of the reaction was decreased
  (iii). A catalyst was added to the reaction mixture

42. (a). Hydrogen reacts with iodine according to the equation

$$H_2(g) \quad + \quad I_2(g) \quad \leftrightharpoons \quad 2HI(g)$$

0.2 moles of iodine and 0.3 moles of hydrogen were enclosed in a 1liter vessel and heated. When equilibrium was attained, 0.36 moles of hydrogen iodide had formed. Calculate the equilibrium constant for the reaction K_c.

(b). Hydrogen reacts with nitrogen according to the equation.

$$3H_2(g) \quad + \quad N_2(g) \quad \leftrightharpoons \quad 2NH_3(g)$$

When 1.65 moles of hydrogen and 0.6 moles of nitrogen were heated to 150°C in a 1.5dm^3 closed vessel, equilibrium was attained when 0.9 moles of ammonia were formed. Calculate the value of equilibrium constant, K_c for the reaction.

(c). Ethanol reacts with ethanoic acid at 50°C according to the following equation

$$CH_3COOH(l) + \quad CH_3CH_2OH(l) \quad \leftrightharpoons \quad CH_3COOCH_2CH_3(l) \quad + \quad H_2O(l)$$

3.12g of ethanoic acid and 2.07g of ethanol were reacted in a 1 liter closed vessel at 50°C. at equilibrium, 0.36g of water were formed. Calculate the value of equilibrium constant for the reaction, K_c.

(d). Methane reacts with steam according to the equation

$$CH_4(g) \quad + \quad 2H_2O(g) \quad \leftrightharpoons \quad CO_2(g) \quad + \quad 4H_2(g)$$

When 0.18 moles of methane and 0.22 moles of steam were heated in a 5 dm^3 vessel, 0.1 mole of carbon dioxide was found to be present at equilibrium. Calculate the value of Kc.

(e). Phosphorus(V) chloride decomposes when heated according to the equation

$$PCl_5\,(g) \quad \leftrightharpoons \quad PCl_3\,(g) \quad + \quad Cl_2\,(g)$$

When 33.36g of phosphorus(V) chloride was heated in a 2.5litre vessel, 8.34g of phosphorus(V) chloride remained at equilibrium. Find then value of Kc.

(f). Nitrogen monoxide combines with oxygen according to the equation

$$2NO(g) \quad + \quad O_2(g) \quad \leftrightharpoons \quad NO_2(g)$$

A closed vessel of 500cm^3 containing 0.33 moles of nitrogen monoxide and 0.355 moles of oxygen was heated. Equilibrium was established when 0.105 moles of oxygen had reacted. Calculate the value of Kc.

(g). Hydrogen reacts with nitrogen according to the equation.

$$3H_2(g) \quad + \quad N_2(g) \quad \leftrightharpoons \quad 2NH_3(g)$$

When 0.58 moles of nitrogen and 1.03 moles of hydrogen were reacted in a 1liter vessel, equilibrium was established when 21.36% of hydrogen had remained. Calculate the value of Kc.

(h). Sulphur dioxide reacts with oxygen according to the equation

$$SO_2(g) \quad + \quad O_2(g) \quad \leftrightharpoons \quad 2SO_3(g)$$

0.425 moles and 0.294 moles of oxygen were heated in a 1.6liter vessel and at equilibrium, it was found that 52.02% of oxygen had reacted. Calculate the value of equilibrium constant Kc.

(i). Sulphur dioxide reacts with oxygen according to the following equation

$$2SO_2(g) \quad + \quad O_2(g) \quad \leftrightharpoons \quad SO_3(g)$$

When 0.6 and 0.425 moles of sulphur dioxide and oxygen respectively were reacted in a 1liter vessel to equilibrium, the equilibrium mixture contained 18.75% sulphur dioxide. Calculate the equilibrium constant value; K_c

(j). Nitrogen reacts with hydrogen to form ammonia according to the equation

$$3H_2(g) \quad + \quad N_2(g) \quad \leftrightharpoons \quad 2NH_3(g)$$

0.8 moles of nitrogen and 0.9 moles of hydrogen were heated in a 1500cm^3 closed vessel. At equilibrium, the mixture contained 20% hydrogen. Find the value of equilibrium constant Kc

(k). Sulphur dioxide dichloride decomposes when heated decomposes according to the equation

$$SO_2Cl_2(g) \quad \leftrightharpoons \quad SO_3(g) \quad + \quad Cl_2(g)$$

When 1.325 moles of sulphur dioxide dichloride were heated in a 2.0l vessel, equilibrium mixture contained 6% sulphur dioxide dichloride. Calculate the value of equilibrium constant, K_c.

(l). Phosphorus(V) chloride decomposes when heated according to the equation

$$PCl_5\,(g) \quad \leftrightharpoons \quad PCl_3\,(g) \quad + \quad Cl_2\,(g)$$

When 266.88g of phosphorus(V) chloride was heated strongly in a 2.5 dm^3 vessel, the equilibrium mixture contained 50% chlorine. Calculate the value of equilibrium constant, K_c.

43. (a). At 1 atmosphere and 48°C, dinitrogen tetraoxide is 30% dissociated.
(i). Calculate the equilibrium constant for the reaction, K_p

(ii). Determine the degree of dissociation of dinitrogen tetraoxide at 48°C and 6 atmospheres

(b). 75.06g of phosphorus(V) chloride were heated to 200°C in 1 dm^3 vessel at a pressure of 170kPa. Calculate the

(i). Degree of dissociation of phosphorus(V) chloride

(ii). Value of equilibrium constant, K_p, at 200°C

44. (a). At 26.7°C, and 25 atmospheres, 20% of phosphorus(V) chloride is dissociated. Calculate

(i). The partial pressure of each component in the equilibrium mixture

(ii). The equilibrium constant, K_p, for the reaction

(iii). The pressure that would be required to increase the dissociation to 30% at the same temperature.

(b). When 0.2 mole of nitrogen and 0.4 mole of hydrogen were introduced in a 1 litre vessel at 300°C and 500 atm equilibrium was attained when 0.18 mole of ammonia was formed. Calculate the equilibrium constant, K_p, for the reaction at this temperature.

(c). When stoichiometric amounts of nitrogen and hydrogen were introduced into a vessel and heated to 250°C and 210 atm, the equilibrium mixture contained 7.5% nitrogen. Calculate the equilibrium constant K_p for the reaction.

(d). When 0.58 moles of nitrogen and 1.03 moles of hydrogen were reacted in a 1liter vessel at 200°C and 350 atm, equilibrium was established when 21.36% of hydrogen had remained. Calculate the value of Kc.

45. (a). Describe an experiment that can be carried out to determine the equilibrium constant values for the reaction between nitrogen and hydrogen.
Nitrogen reacts with hydrogen according to the equation

$$3H_2(g) \quad + \quad N_2(g) \quad \leftrightharpoons \quad 2NH_3(g)$$

(b). 0.2 mole of phosphorus(V) chloride was heated in 1 dm^3 vessel at 160°C and a pressure of $8.0 \times 10^5 Nm^{-2}$. Calculate the

(i). Degree of dissociation of phosphorus(V) chloride

(ii). Value of equilibrium constant; K_p, for the reaction at 160°C.

46. In the manufacture of ammonia, nitrogen is catalytically hydrogenated to give ammonia according to the following equation.

$$3H_2(g) \quad + \quad N_2(g) \quad \leftrightharpoons \quad 2NH_3(g) \qquad \Delta H = +92.5kJ$$

(a). (i). Name the catalyst used in the reaction

(ii). Write down the expression for the equilibrium constant. Kp, for the reaction

(b). State what would happen to the position of the equilibrium if;

(i). Pressure was increased.

(ii). Temperature was increased.

(c). When 3 moles of hydrogen and 1 mole of nitrogen were mixed and allowed to attain equilibrium at 100 atm and 400°C, the equilibrium mixture contained 25% of ammonia by volume. Calculate the;

(i). Number of moles of nitrogen and hydrogen at equilibrium

(ii). Value of the equilibrium constant, Kp, at 400°C

47. In the industrial preparation of sulphuric acid by contant process, sulphur dioxide reacts with oxygen according to the following equation.

$$2SO_2(g) + O_2(g) \leftrightharpoons 2SO_3(g)\,;\, \Delta H = -188kJmol^{-1}$$

(a). Explain what would happen to the concentration of sulphur trioxide if;

(i). More sulphur dioxide was added

(ii). The volume of the reaction vessel was increased

(iii). The reaction vessel was cooled

(b). At 700°C, and total pressure of 1.0 atm, the partial pressure at equilibrium for sulphur dioxide and oxygen are 0.27 and 0.41 atm respectively. Calculate the equilibrium constant, Kp for the reaction